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The importance of sustained attention for patients with maculopathies

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Abstract

Sustained attention enhances perception in eccentric positions in the visual field, which helps patients with foveal vision loss to develop a peripheral 'preferred retinal locus' (PRL). Besides central scotoma topography, local variations of attentional performance could influence the choice of PRL location. We tested sustained attention augmenting peripheral letter recognition in 23 maculopathy patients and 15 normally-sighted subjects (eight positions, 8° eccentricity). Performance was shown to depend on tested location, which was the same in patients and normals. This indicates that the choice of the PRL location after foveal vision loss can be influenced by topographic features of sustained attention.

Keywords: Sustained attention; Maculopathy; Preferred retinal locus; Fixation

1. Introduction

By an 'effort of will', we can pay attention to a location in the visual field without looking at it directly, which facilitates recognition of targets (von Helmholz, 1896). This 'sustained' component of attention (Nakayama & Mackeben, 1989) seems to be mediated by a part of the parietal cortex (Posner & Petersen, 1990). Even though the role of attention in vision has been intensively studied, it is still not easy to associate this ability with real-life tasks. An exception is maintaining visual functionality after binocular foveal vision loss. This condition can be caused by maculopathies, most frequently age-related maculopathy (ARM), and invariably results in losing the ability to read and recognize faces (Bullimore, Bailey & Wacker, 1991; Trauzettel–Klosinski & Tornow, 1996).

Once the exceptional spatial resolution of the fovea cannot be used to analyze images, a peripheral retinal locus can take over this function. This technique is called 'eccentric viewing' and has been shown to be the only way, in which patients with maculopathies can achieve their most important goal: to learn to read again (Otto, 1969; Aulhorn, 1975; Goodrich & Mehr, 1986; Nilson & Nilson, 1986; Trauzettel–Klosinski, Teschner, Tornow & Zrenner, 1994). The effort requires two components: (1) using some form of optical magnification to compensate for the lower spatial resolution of the peripheral retina; and (2) turning the eyes in such a way that the image of the object of interest falls onto the 'preferred retinal locus' (PRL, von Noorden & Mackensen, 1962; Timberlake, Peli, Essock & Augliere, 1987).

The position of the PRL will, most importantly, be influenced by the 'geographic' distribution of damage to the retina (Sunness, Applegate, Haselwood & Rubin, 1996). Beyond that, it is important to know the most desirable PRL location for reading. It has been argued that the patient should lift the eyes slightly, so that the word to be read falls on a retinal locus right above the lesion, i.e. below the scotoma in the visual field (Bäckman & Inde, 1970; Faye, 1984; Nilson & Nilson, 1986). That way, there is enough intact retina on both sides of the PRL to provide sufficient horizontal fields of view to get through the current line and to find the beginning

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of the next line. Studies using scanning laser ophthalmoscopes (SLOs), however, have provided strong evidence that in reality this is not what patients with binocular foveal vision loss do (Guez, Le Gargasson, Rigaudière & O'Regan, 1993; Trauzettel–Klosinski & Tornow, 1996; Sunness et al., 1996; Fletcher & Schuchard, 1997). A significant portion of patients in these studies (21–63%) positioned their PRL so that it was left of the scotoma in the visual field! Consequently, when these patients read, they have to make forward saccades into the scotoma several times per line.

As this puzzling behavior is not likely to make reading any easier, there must be another factor influencing this odd choice of PRL location. Based on a study in normally-sighted subjects, it has been proposed by Mackeben (1999) that an additional element may be a topographic component of sustained attention. This means that the willful deployment of sustained attention to some locations in the visual field may be easier than to others. If true, this would mean that patients with maculopathies face a further limitation of their options that is unrelated to their eye disease, but rather a function of their normal visual system.

This study was conducted to investigate: (1) whether there are any significant differences in attentional performance between the patient group with maculopathy and normally-sighted subjects; and (2) whether there is direct evidence derived from a group of relevant patients to support the attention hypothesis.

Assuming that a location with higher attentional capability is a more likely PRL candidate, this allows the conclusion that these patients' future choices of the location of preferred retinal loci for eccentric viewing will, among others, be influenced by irregularities in the spatial distribution of attentional capabilities. As a practical consequence, this may open new possibilities for goal-directed training in those patients with beginning maculopathies who show poor attentional performance in locations that are especially suited for eccentric viewing with regard to reading.

2. Methods

2.1. Apparatus

The test was generated and controlled by a specially designed computer program based on the study by Mackeben (1999) and adapted for the IBM PC and compatibles by Aleksandr Gofen (Smith-Kettlewell Eye Research Institute, San Francisco). The program was written in Delphi (Borland-Inprise). the hardware consisted of an IBM PC compatible computer (Intel Pentium II) and a Philips 107B display monitor.

2.2. Subjects

We investigated two groups, a patient group ($N = 23$; age 14–76 years; mean 38 ± 16.6) with maculopathies (determined by availability: 12 with Stargardt's disease, five with Best disease, three with ARM, two with other juvenile maculopathies, one with x-linked retinoschisis) and a control group of normally sighted subjects ($N = 15$; age 23–68, mean: 39.0 ± 17.6). If necessary, all subjects were tested with their optimal refractive and presbyopic correction.

Inclusion criteria for patients were:

1. Early stage of maculopathy with a beginning macular scotoma but still intact foveal fixation. The fixation locus was ascertained by a SLO (Rodenstock; position of the anatomical fovea in relation to the stimulus) and/or the position of the blind spot as reference scotoma in 30° perimetry (Tübingen Automated Perimetry) (Trauzettel–Klosinski, 1997).
2. No scotoma at 8° eccentricity, as this was the tested area, based on perimetry.

The subjects of the control group had no history of eye disease or serious general health problems.

The examination was in agreement with the declaration of Helsinki and all subject gave their informed consent.

2.3. Stimuli and pretesting

Targets were 'tumbling' Snellen E's of either 34 or 40 arcmin in angular extent. At target/background contrast of 98%, this should be safely above threshold (Strasburger, Harvey & Rentschler, 1991). Distractors were designed to contain the same space-averaged luminance as the targets to prevent cueing the target location by a difference in brightness.

Preliminary tests determined the size of the Snellen E's and duration (60–190 ms) to be used for each subject (using the same procedure as in the main experiment). To make sure that there was no chance that spatial resolution could limit performance, this was tested in each subject and in all tested locations by displaying a target for a duration of 1 s. At this duration, the responses were all correct.

The target duration had to be shorter than 200 ms to prevent foveating saccades to the target. Starting with a target size of 34 arcmin, the target duration was increased in steps until the subject was able to recognize the targets in at least two of the locations without problems ($> 75\%$ correct). If the subject still did not perform well with a target size of 34 arcmin and a duration of 190 ms, the 40 arcmin targets were used.

The test was performed on the dominant eye, while the fellow eye was covered. To determine the dominant eye, the subject was asked to look through a pinhole in a paper. The eye the subject spontaneously chose for looking through the pinhole was assumed to be the dominant eye.

2.4. Procedure

Subjects were seated in front of a computer monitor at a viewing distance of 65 cm. All tests were performed monocularly. Subjects maintained fixation on a cross in the middle of the screen. Fixation of the central mark was monitored by the examiner using an infra-red camera and TV monitor, all sessions were recorded on videotape. If fixation was unstable during a trial, the subject's answer was not entered (space key) and a trial with the same target and location was automatically repeated at the end of the trial block.

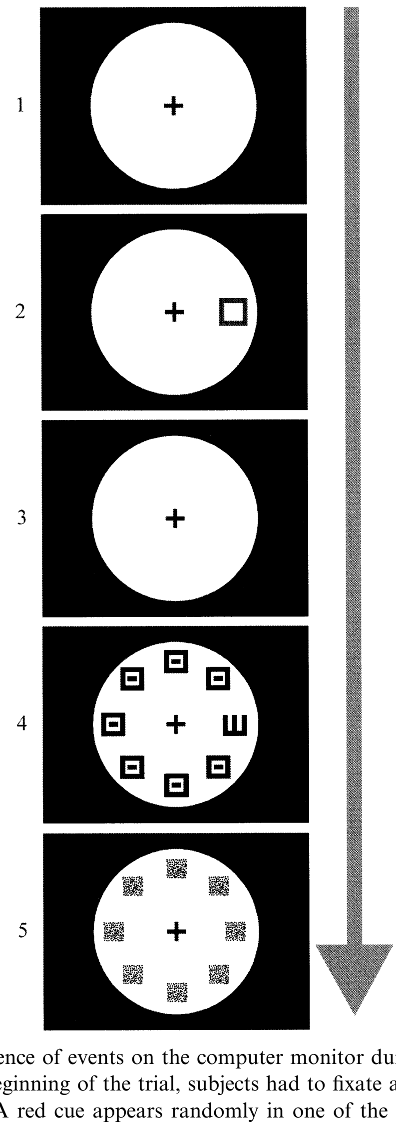

Fig. 1. Sequence of events on the computer monitor during one trial. (1) At the beginning of the trial, subjects had to fixate a central cross for 1 s. (2) A red cue appears randomly in one of the eight possible positions at 8° eccentricity for 1 s. (3) Attention has to be held in the previously position for 2.5–4 s. (4) The target, a Snellen E, appears at the cued location and seven distractors in the others for 60–200 ms. The task was to determine the orientation of the E while maintaining fixation of the central cross. (5) Masks were displayed for 100 ms in all eight locations.

Eight locations were tested at 8° eccentricity (0, 45, 90, 135, 180, 225, 270 and 315°). The upcoming test location was indicated for 1 s by a red square cue (60×40 arcmin). The subject was asked to shift attention to that location without shifting the direction of gaze. This was followed by a 2.5–4 s delay, during which attention had to be held at the cued location. After the randomly chosen delay, a Snellen E appeared in the cued location for 60–190 ms, while distractors appeared in the other seven locations. Target and distractors were immediately followed by masks of 100 ms duration. The procedure used here was identical with the one described by Mackeben (1999), with the exception of the different targets (Snellen E's versus letters) and the lower number of trials per location (Fig. 1).

The task was to recognize the open side of the 'tumbling' E, which could be any of four positions: up, down, right and left. The subject's verbal response was entered on the computer keyboard by the examiner. The response was scored by the test program and stored in a data file. There were 24 individual trials in a block, in which the tested locations were unpredictably varied, so that all eight locations were tested three times/block. Four of these trial blocks were run with each subject, so that each location was tested 12 times altogether. Limited availability of the subjects (1 h each) prevented more extensive testing.

3. Results

The findings of this study can be grouped as results of comparisons between tested locations within subjects and of comparisons between subjects.

3.1. Comparisons between locations within subjects

Results are shown numerically in Table 1, and an example can be seen in the polar diagram in Fig. 2. The percentage of correct responses is marked as the lengths of the vectors on the meridians (0–315°), and their directions indicate the tested location in the visual field. Neighboring end points are connected by straight lines to form 'attentional fields'.

The paradigm allows formulating the null-hypothesis that recognition performance should be the same in all locations, which would result in fields looking like regular octagons (see dotted line in Fig. 2). As it is obvious from graphical comparison, the real and the 'ideal' data based on H_0 differ strongly. We needed to substantiate that the data were not due to random variation around a mean or to sampling error. To that end, we established confidence limits for the eight values of each subject ($P \pm 1.96$* SE (with $P < 0.05$)) and examined whether the mean of the eight values fell outside these limits. (Note that calculating the mean of

Table 1
Columns of all data collected from 23 patients[a]

Patient No.	Visual acuity	Age	Sex	Disease	Scotoma (°)	Target		Test results (°)							
						Size (arcmin)	Duration (ms)	0	45	90	135	180	225	270	315
1*	0.8	21	F	BD	1	34	160	83 ± 10.8	83 ± 10.8	25 ± 12.5	75 ± 12.5	100	50 ± 14.4	41 ± 14.2	58 ± 14.2
2*	0.8	71	F	AMD	Crls	40	100	100	67 ± 13.6	50 ± 14.4	75 ± 12.5	83 ± 10.8	92 ± 0.8	75 ± 12.5	100
3*	0.8	42	M	SD	1–3	40	100	100	75 ± 12.5	33 ± 13.6	92 ± 0.8	100	92 ± 0.8	92 ± 0.8	92 ± 0.8
4	0.4	29	F	SD	1–5	34	190	67 ± 13.6	67 ± 13.6	33 ± 13.6	17 ± 10.8	75 ± 12.5	50 ± 14.4	50 ± 14.4	58 ± 14.2
5	0.7	26	F	SD	1–3	40	120	58 ± 14.2	75 ± 12.5	42 ± 14.2	83 ± 10.8	92 ± 0.8	83 ± 10.8	75 ± 12.5	67 ± 13.6
6*	0.2	54	M	BD	1	40	180	100	92 ± 0.8	58 ± 14.2	67 ± 13.6	83 ± 10.8	42 ± 14.2	25 ± 12.5	83 ± 10.8
7*	0.6	21	M	SD	1–5	34	180	100	42 ± 14.2	50 ± 15.4	67 ± 13.6	100	100	67 ± 13.6	83 ± 10.8
8	0.8	45	M	SD	1–3	34	120	67 ± 13.6	75 ± 12.5	42 ± 14.2	67 ± 13.6	67 ± 13.6	42 ± 14.2	83 ± 10.8	67 ± 13.6
9	0.4	14	M	Ret.	1–3	34	180	92 ± 0.8	67 ± 13.6	67 ± 13.6	75 ± 12.5	92 ± 0.8	75 ± 12.5	50 ± 14.4	50 ± 14.4
10*	0.8	35	M	SD	1–3	40	100	100	100	83 ± 10.8	67 ± 13.6	100	75 ± 12.5	50 ± 14.4	100
11*	0.6	69	M	AMD	1	40	100	75 ± 12.5	83 ± 10.8	33 ± 13.6	92 ± 0.8	100	92 ± 0.8	58 ± 14.2	83 ± 10.8
12*	0.2	30	M	SD	1–5	40	80	100	92 ± 0.8	58 ± 14.2	83 ± 10.8	100	50 ± 14.4	33 ± 13.6	83 ± 10.8
13*	0.6	21	M	SD	1–3	40	60	83 ± 10.8	42 ± 14.2	83 ± 10.8	83 ± 10.8	100	75 ± 12.5	92 ± 0.8	75 ± 12.5
14*	0.8	53	M	BD	1–3	40	180	92 ± 0.8	83 ± 10.8	50 ± 14.4	100	100	100	58 ± 14.2	83 ± 10.8
15*	0.3	15	M	SD	1–5	40	100	42 ± 14.2	58 ± 14.2	33 ± 13.6	83 ± 10.8	100	100	92 ± 0.8	75 ± 12.5
16*	0.13	76	M	AMD	1	40	160	67 ± 13.6	58 ± 14.2	25 ± 12.5	100	100	100	67 ± 13.6	75 ± 12.5
17*	1.0	28	F	SD	1–3	34	180	100	67 ± 13.6	33 ± 13.6	75 ± 12.5	100	75 ± 12.5	67 ± 13.6	83 ± 10.8
18*	0.7	38	F	SD	1–3	40	160	83 ± 10.8	33 ± 13.6	33 ± 13.6	75 ± 12.5	100	83 ± 10.8	83 ± 10.8	100
19*	1.0	41	F	BD	Crls	34	100	100	83 ± 10.8	42 ± 14.2	100	100	83 ± 10.8	58 ± 14.2	75 ± 12.5
20*	0.2	36	M	JM	1	40	80	92 ± 0.8	83 ± 10.8	33 ± 13.6	75 ± 12.5	92 ± 0.8	83 ± 10.8	75 ± 12.5	67 ± 13.6
21	0.2	56	F	BD	1–3	40	80	100	92 ± 0.8	58 ± 14.2	83 ± 10.8	92 ± 0.8	67 ± 13.6	83 ± 10.8	83 ± 10.8
22	0.8	44	M	JM	1–5	40	120	92 ± 0.8	75 ± 12.5	58 ± 14.2	75 ± 12.5	92 ± 0.8	92 ± 0.8	100	92 ± 0.8
23	0.5	31	F	SD	1–5	34	120	83 ± 10.8	67 ± 13.6	33 ± 13.6	100	92 ± 0.8	83 ± 10.8	92 ± 0.8	92 ± 0.8

[a] From left to right: Patient number; * $P<0.05$ in Fisher's exact test; visual acuity ($1.0 = 20/20 = 6/6$); age; sex; diagnosis (BD, Best Disease; ARM, age-related maculopathy; SD, StargardtDisease; JM, other juvenile maculopathy; Ret, x-linked retinoschisis); radius of the central scotoma (°); Crls, centrally reduced sensitivity to light differences (Aulhorn & Harms, 1972); Snellen E target height (in arcmin); target duration (in ms); scores (% correct and the standard errors of a proportion) for the eight positions.

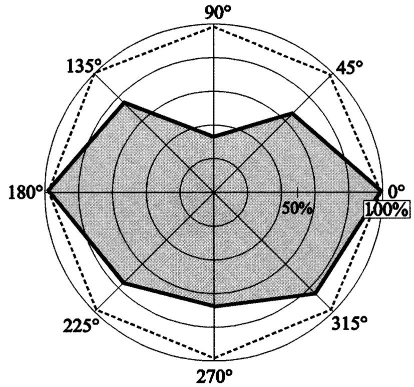

Fig. 2. Polar diagram of letter recognition performance of Patient No. 17. There were 12 trials in each of the eight positions (0–315° in the visual field at 8° eccentricity). The percentage of correct responses is shown as length of the vectors on each meridian. Concentric rings denote, from outer to inner: 100; 80; 60; and 40%. The ends of neighboring vectors are connected to form an 'attentional field'. In this example, performance is reduced in the 90° position. The regular octagon shows the 'ideal' attention field if performance were maximal in all eight positions.

'all' patients would be inappropriate here, because the absolute values are dependent on experimental conditions, which varied between subjects.)

The result is that the number of significantly different values in 22 patients lay between one and five per subject (mean $= 2.86 \pm 1.21$ SD, $P < 0.05$). The same number for the 15 normal subjects lay between one and six (mean $= 3.07 \pm 1.34$). This indicates for both groups that it is unlikely that the observed location-dependent variations are caused by random variation around a mean. These numbers did not differ significantly between the subject groups according to an unpaired t-test ($t = 4.81$, $P = 0.633$).

This result was supplemented by a different approach of analysis using Fisher's (Freeman-Halton's) exact test, which can determine independence within the rows and columns of a table by testing whether the relation of correct to incorrect responses are the same in all locations (H_0). For this purpose, our data were reformulated as 8×2 contingency tables (eight locations versus number of correct and incorrect responses). The results express the likelihood in P-values that H_0 is true. The P-values lay between 0.0001 and 0.3825. Using a criterion of $P < 0.05$ as acceptable statistical significance, we found that the null-hypothesis can be rejected for 17 of the 23 patients. The same was true for 14 of the 15 normal subjects (P-values between 0.0001 and 0.1743). In the patients, 14 of the values indicated significance levels of $P < 0.01$, while the same was true for 10 of the normal subjects.

We conclude from both these analyses that it is highly unlikely, at least for most of our subjects, that the observed location-dependent variations of performance were caused by random variation around a mean.

3.2. Comparisons between subjects

As target size and duration were adjusted individually, the results are not comparable on an absolute scale.

(1) Relative comparison between the shapes of the fields and observing the performance minima in each subject allowed dividing them into three groups (see Fig. 3). Graphical comparison (Fig. 3) as well as the original data (Table 1) show that all but one subject had a considerable performance deficit in either or both locations on the vertical meridian by a criterion of 60% of the individual's best performance. By that criterion, 21 of 37 subjects (first group, Fig. 3) showed reduced attentional performance in the upper part of the visual field. The mean ratio of 90/270° for this group was 0.59 ± 0.16 ($n = 16$). The second group was formed by six of 37 subjects showing reduced performance in the lower part of the visual field. For this group, the mean of the 90/270° ratio was 1.64 ± 0.29 ($n = 5$). Attentional deficits in both vertical locations were observed in ten subjects, for whom the mean 90/270° ratio was 1.03 ± 0.55 ($n = 11$).

We tested the validity of this observation by taking the mean of the two values on the horizontal meridian and comparing it separately with both individual values on the vertical meridian (above and below the center).The results show that 13 of the 23 patients had one value on the vertical meridian that differed significantly from the mean horizontal with $P < 0.05$, and seven other patients had two such values. In the control group, 6/15 subjects had one significantly different value, while 7/15 others had two.

Secondly, we also compared the values on the vertical meridian to the mean of all eight values in each individual. We found that in 11 of 23 patients, one value on the vertical meridian was significantly different from the mean (nine of them with $P < 0.05$, two with $P < 0.1$). In four patients, both values on the vertical meridian that were significantly different from the mean, with at least one of the pair at $P < 0.05$, the other with $P < 0.1$. Of the 15 control subjects, six had one vertical value that was significantly different from the mean with $P < 0.05$, while for seven subjects both were significantly different from the mean.

We conclude that the observed differences of performance between the locations on the horizontal and vertical meridians cannot be explained by random variation.

(2) The second important finding was that there were no differences between subject groups, neither comparing the patients with the control group in the present study nor with the normal group in the study by Mackeben (1999).

A further finding was that almost all subjects performed better on the horizontal meridian than on the

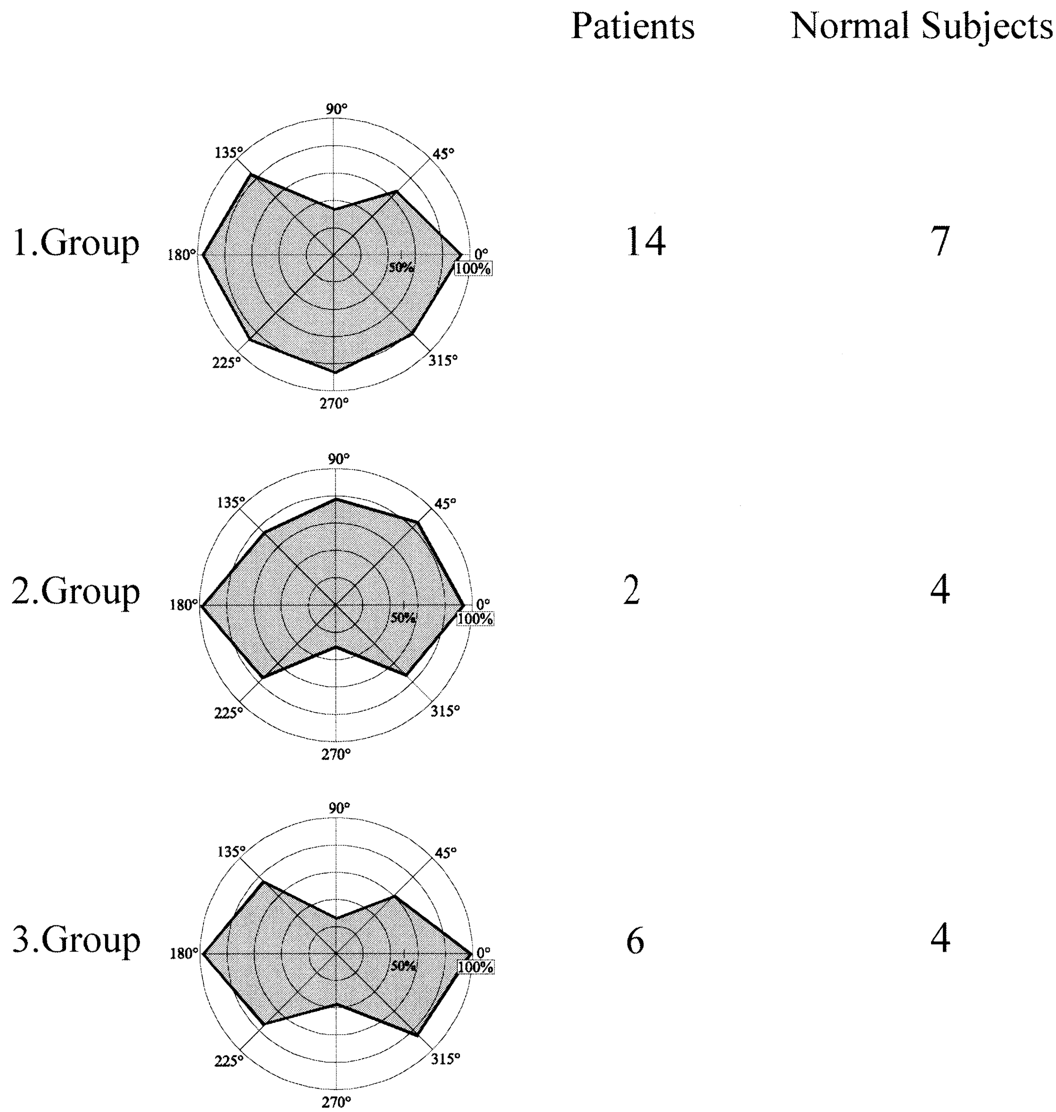

Fig. 3. Polar diagrams of 23 patients (all but one, Patient No. 13) and 15 normal subjects are divided into three groups according to deficits in attentional performance (< 60% correct responses). First group, deficit in the upward position (90°); Second group, deficit in the downward position (270°); Third group, deficit in both, the upward and downward position (90 and 270°). The columns 'Patients' and 'Normal Subjects' show the number of subjects in each of the three groups.

vertical meridian. To investigate this, we compared performance on the horizontal meridian ($h = 0 + 180°$) with that on the vertical meridian ($v = 90 + 270°$) for all subjects. The mean ratio for the normals (h/v) is 1.66 (± 0.44) and for the patient group 1.66 (± 0.39). Again, no differences between the patients and normals were found.

(3) All subjects showed the ability to fixate foveally with the tested eye, as assessed monocularly by SLO. However, there were nine of 23 patients who already fixated eccentrically with their fellow eye, i.e. the one not tested in the attention test. In these nine patients, we could compare the position of the PRL of the eccentrically fixating eye with the results of the sus-

Fig. 4. Comparison in nine patients of polar attention fields from the centrally fixating eye with the PRL of the eccentrically fixating fellow eye. The columns (left to right) denote: patient-number; attentional fields of the centrally fixating eye; fundus of the eccentrically fixating fellow eye (assessed by SLO); the cross indicates the PRL relative to the lesion (upwards in SLO corresponds to downwards in perimetry); arrows showing the direction of shift of the central scotoma (in the visual field) in the eccentrically fixating eye; 30° perimetry of the eccentrically fixating eye, eccentric position of the central scotoma and the blind spot. The attentional fields of Patients No. 18, 7, 13, 15, 23 and 4 show better performance in the lower than in the upper field, which corresponds with eccentric fixation below the central scotoma of the fellow eye. Patient No. 12 and 14 show reduced attentional performance upwards and downwards, their eccentrically fixating fellow eyes showed a PRL on the left (No. 12) and on the right side (No. 14) of the central scotoma. Patient 8 was the only exception and fixated eccentrically on the lower left of the scotoma, which did not correspond to a location with good attentional performance in the centrally fixating eye.

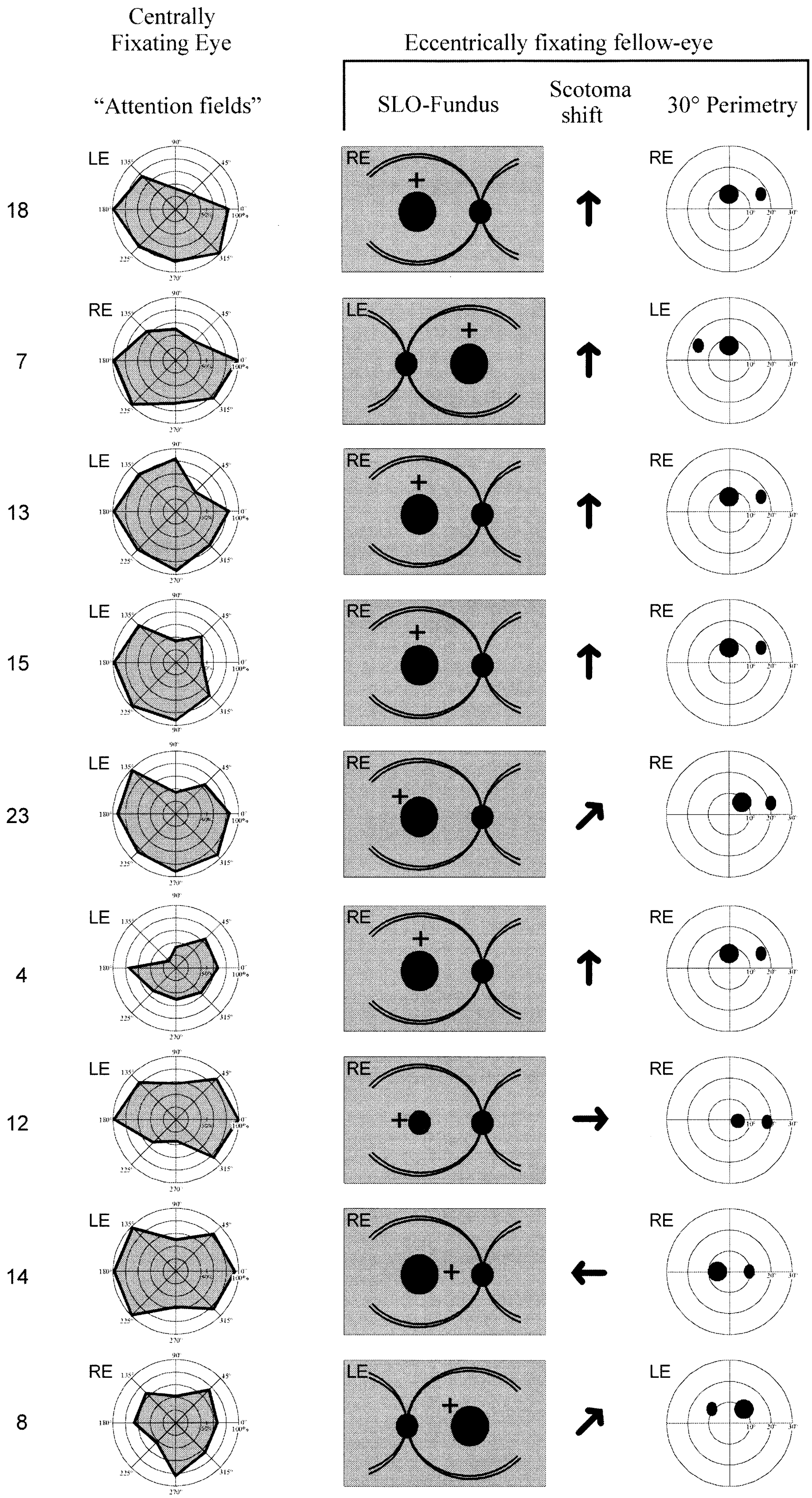

Fig. 4. (*Caption opposite*)

tained attention test of the foveally fixating fellow eye (see Fig. 4.)

When the SLO fundus and the visual field are compared, the image has to mirrored at the 0° meridian (upwards in the SLO corresponds to downwards in perimetry). In eight of these patients, the PRL of the eccentrically fixating eye was placed in a location corresponding with a fellow location showing good attentional performance in the centrally fixating eye. In six patients (No. 18, 7, 13, 15, 4 and 23), recognition performance of the centrally fixating eye was impaired in the superior visual field, and the PRL in the eccentric fellow eye was placed below the central scotoma in the visual field (lower left side of the central scotoma in Patient No. 23).In two patients (No. 12 and 14), performance was reduced on the 270° meridian or lower visual field of the centrally fixating eye, and the PRL of the fellow eye was either placed on the left side of the central scotoma (No. 12) or on the right side (No. 14). There was one exception (Patient No. 8, Fig. 4), who placed the PRL on the left side of the central scotoma (in the visual field) in the eccentrically fixating eye while the attentional performance of the centrally fixating eye was reduced in this position (225°).

4. Discussion

Two steps were taken to make sure that the found topographic differences in performance indeed reflected properties of sustained focal attention: (1) we ascertained for each patient that there was no scotoma in any of the tested areas at 8° eccentricity; and (2) our pre-tests ensured that target sizes were always above the size threshold according to Westheimer (1982) and Strasburger et al. (1991).This selection was then confirmed by running tests with a target duration of 1 s, which always resulted in perfect scores.

We knew from an earlier study (Mackeben, 1999) that performance levels can differ strongly between subjects. The main goal of this investigation was to measure differences between tested positions within a subject, not the absolute performance level. This is why our subjects used different target sizes and durations, because variable settings that make target recognition virtually impossible for one subject may make the task perfectly easy for another.

On the other hand, the target duration in the attention test was chosen so short, that the orientation of the ‘tumbling’ Snellen E could only be recognized with the help of focal attention. This was confirmed by indirect evidence derived from Mackeben’s study (1999), where subjects were also tested with similar target durations, but without the cue. The results showed that not knowing in which location the target would appear reduced the subjects’ performance considerably, as they had only little time available to activate the ‘transient’ component of attention to aid perception (Mackeben, 1998).

We found that for some subjects (57%) it was harder to deploy sustained attention above the center of the visual field, for others it was more difficult to shift it downward (16%), or even in either direction (27%). This tendency was also described in Mackeben’s (1996, 1999) studies for normal subjects. This is in contrast with the findings by He, Cavanagh and Intriligator (1996) who found that sustained attentional resolution was reduced in the upper visual field in all their subjects ($n = 4$). The present study used the same paradigm as the previous one (Mackeben, 1999), so that the results can be regarded comparable, which gives us a comparison between 50 subjects altogether. We suggest that the difference in findings can be adequately explained by the difference in sample size.

These points lead to the conclusion that a reduction of letter recognition performance in particular locations in maculopathy patients as well as normally sighted subjects can be explained by topographic variations of the focal attention mechanism.

The fact that performance in some position reached 100% correct responses can be explained by a ceiling effect according to Weber’s law. The stimulus intensity was too high in these positions, so that the target duration should have been decreased and the whole test repeated with the adjusted target duration. This was not possible, as availability of all patients was limited to a maximum of 1 h, and jeopardizing the solidity of the data by reducing the number of trials per location was not an acceptable option. On the other hand, making the test too hard by choosing a shorter duration from the start was avoided to prevent frustration on the part of the subjects.

We could not determine any differences in attentional performance between the patients and normal subjects. Hence, it is legitimate to assume that the same topographic variations in attentional performance found in normals (see Mackeben, 1999 and the present study) are still valid after acquiring a small macular scotoma.

We assume that patients with good performance in the lower visual field are likely to choose a PRL below the scotoma, especially for reading. On the other hand, reduced attentional performance in the lower field could make patients more inclined to put their PRL on the left or right of the central scotoma in the visual field. A PRL either below or on the left side of the scotoma in the visual field is found in most patients with eccentric fixation due to foveal vision loss (Guez et al., 1993; Trauzettel–Klosinski & Tornow, 1996; Fletcher & Schuchard, 1997).

The results of this study present the first direct evidence to substantiate the concept that there might be a correlation between locations with good attentional capabilities and the future PRL location (Mackeben, 1996, 1999). The definitive evidence will be available only after the patients investigated here start fixating eccentrically with the investigated or both eyes. The fact that eight of nine patients with an eccentrically fixating fellow eye showed a PRL position corresponding to a location with good attentional performance tested through the other eye can be regarded as an indicator of future developments of their gaze strategies.

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